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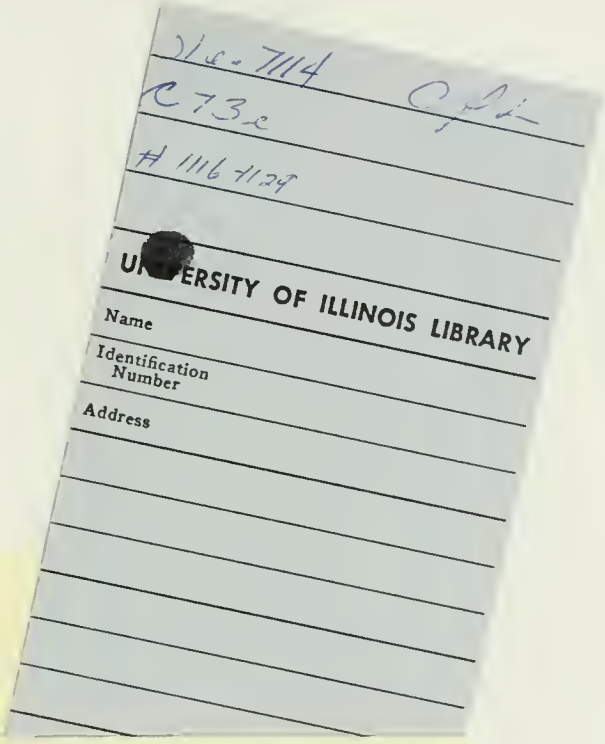
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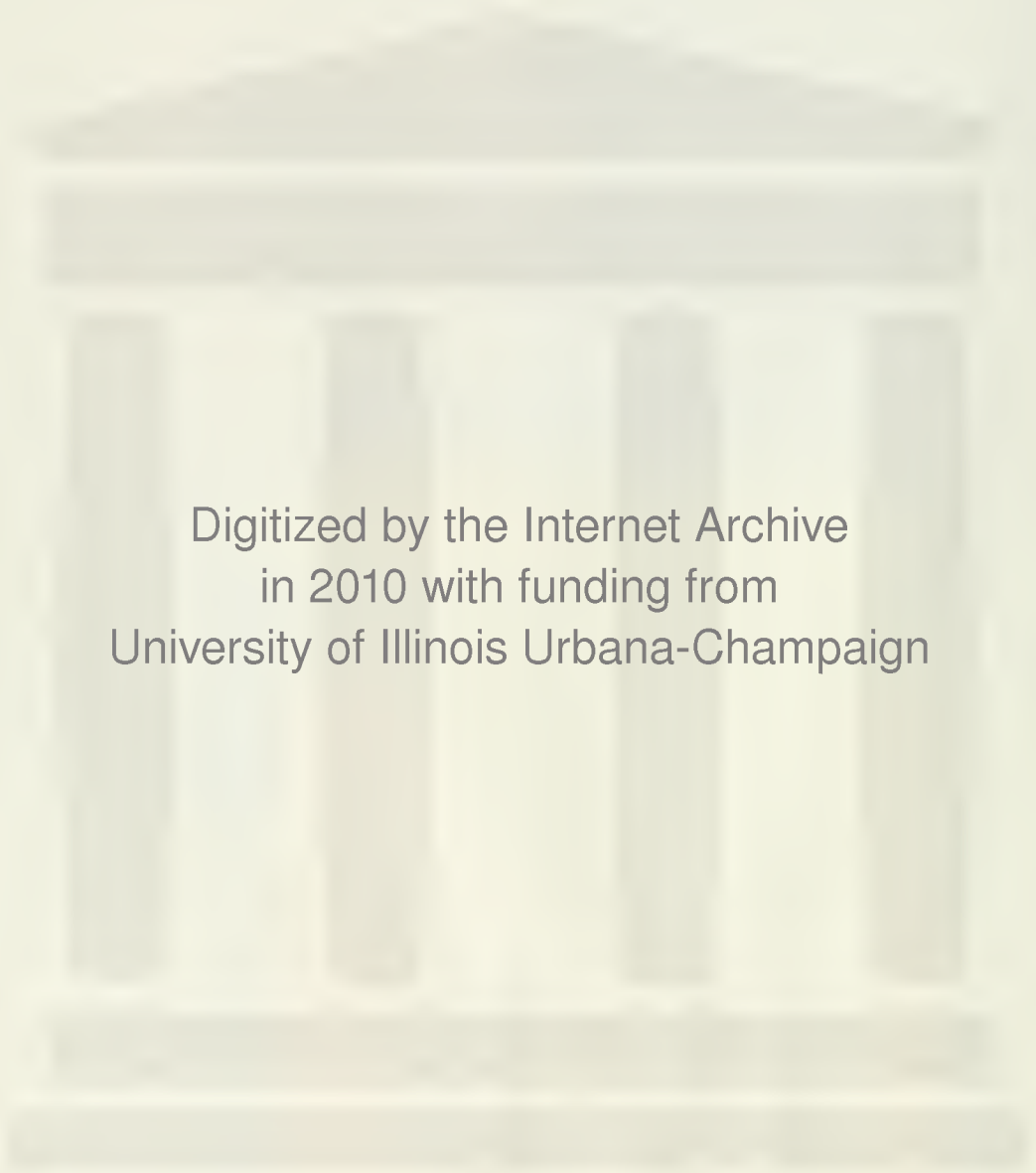

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REMOTE SENSING APPLICATIONS TO WATER QUALITY ASSESSMENT: An Annotated Bibliography of Selected Literature, 1970 to 1975

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REMOTE SENSING APPLICATIONS TO WATER QUALITY ASSESSMENT: AN ANNOTATED BIBLIOGRAPHY OF SELECTED LITERATURE, 1970-1975

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Introduction

During the late 1960's and continuing to the present, there has been a substantial increase in remote sensing technology. LANDSAT, Skylab, numerous high flight missions, and refinement of both active and passive sensor systems are illustrative. Water quality assessment has been enhanced through many remote sensing technological advancements; this bibliography is an overview of selected applications as found in the literature of the 1970-1975 period.

Applications of Remote Sensing to Water Resources

It should be clear that remotely sensed data is not the panacea for the requirements of water resource monitoring. Remote sensors are valuable tools which most often must be used in conjunction with related measurements. For example, when a pollution source is noted from remotely sensed imagery, ground level measurements are often needed to specify the type and concentration of pollutant.

Generally, there are three categories of remote sensing application to water resource assessment. First, there are simple

qualitative observations. These would include the use of imagery to locate effluents, plumes, oil slicks and similar variations. Secondly, geographic and dimensional data can be ascertained. Delineation of water bodies, watersheds, ground water sources and channel networks are some possibilities. Finally, the third category entails correlation of remotely sensed data to water based measurements. Included in this category are analysis of spatial phenomenon which can be monitored by point sampling. Thermal pollution reconnaissance via thermal scanners is a good example.

The advantages of remote sensing over ground measurement are substantive. The bird's-eye view which is afforded by platform sensors provides quite detailed coverage of water and land resources over expansive areas. Monitoring of water resources over time is further enhanced through the use of remote sensors, especially in view of the area wide coverage. Applications of LANDSAT data have demonstrated such temperal monitoring capability. Of particular advantage is the fact that certain sensors can explore spectral energy which the eye cannot detect. Thus the range of applications is appreciably enhanced.

Besides monitoring of water quality, other remote sensing applications in the field of water resources include measurement of the following: evapotranspiration; soil moisture; lakes, marshes and swamps, including water color, depth, temperature, and hydrobiological studies; drainage basin and channel networks; chemical characteristics; snow and ice extent; urban hydrological phenomena;

groundwater, including discharge, gaining and losing streams, and shallow aquifer location; and flocd mapping.

Sources of Remote Sensing Information for Water Resources Studies

This bibliography was gleaned from two primary sources: (1) Selected Water Resources Abstracts which is compiled for the Water Resources Scientific Information Center, U. S. Department of the Interior by the National Technical Information Service; and (2) the International Aerospace Abstracts (IAA) which is prepared by the Technical Information Service of the American Society of Aeronautics and Astronautics for NASA. The first source provides selected references including journal articles, symposium papers and technical reports. The IAA series covers most periodicals and symposiums in the field of remote sensing.

Two other annotated listings should be mentioned as excellent sources of current remote sensing research efforts. The National Technical Information Service (NTIS) of the Department of Commerce prepares the biweekly Government Reports Index; generally, most studies which entail federal funding are listed. Even more thorough, as to remote sensing citations, are the Scientific and Technical Aerospace Reports (STAR). This NASA publication is developed similarly to the IAA series; the same key words are used. It primarily contains technical report citations of federally funded research. It overlaps somewhat with the NTIS reports as far as remote sensing listings; however, it is generally more complete.

All the preceding are annotated. The individual citations are referenced by a series of key words. Computer searches are possible;

however, access would vary depending on the network to which the agency or resource library is enjoined. The NTIS Government Reports Index is the most readily accessible system of the preceding sources.

Style and Organization

The Chicago Press Style for the natural sciences is used throughout this bibliography. Authors' abstracts are generally included; occasionally, such abstracts have been modified by this compiler to maintain concise entries. The authors' abstract and the selected Water Resources Abstracts are noted simply by "author" or "WRA" under each listing.

The citations are listed in alphabetic order. An alphabetic-numeric code has been assigned to each entry in order to facilitate use of this bibliography. Such codes are matched with the appropriate subject area in the index following the citations.

A1. Alexander, S. S., D. Dein and D. P. Gold. 1973. The Use of ERTS-1 MSS Data for Mapping Strip Mines and Acid Mine Drainage in Pennsylvania. In Symposium on Significant Results Obtained from the Earth Resources Technology Satellite-1. Vol. 1, pp. 569-575. Houston: NASA.

Digital processing of ERTS-1 MSS data for areas near the west branch of the Susquehanna River permits identification of stripped areas including ones that are not discernible from visual analysis of ERTS imagery. Underflight data and ground-based observations are used for ground truth. Preliminary results indicate that ERTS data can be used to monitor not only the total extent of stripping in given areas but also the effectiveness of reclamation and pollution abatement procedures. WRA modified

A2. Aukland, J. C. and D. T. Trexler. 1970. Oil Pollution Detection and Discrimination by Remote Sensing Techniques. U. S. Coast Guard Report No. 714104/A/006-1. 166 p. Available NTIS: AD-716349.

Detection of oil pollution by using airborne remote sensing was performed in the Gulf of Mexico during April 1970. Number 2 fuel oil, number 6 fuel oil, 9250 lube oil, light crude oil, heavy crude oil, gasoline, and oil and gas mixtures were investigated. Two dual polarized microwave radiometers, an infrared scanner, a dual 70 mm camera and a 4-lens camera with filters from the mid-visible to ultraviolet wavelengths were used. WRA

A3. Aukland, J. C., D. T. Trexler and F. Orthlieb. 1971. Multi-sensor Oil Spill Detection. In Proceedings of the 7th International Symposium on Remote Sensing of Environment. Vol. II, pp. 1045-1052. Ann Arbor: Michigan University.

A significant amount of data was collected for an insight into the type of sensors required for an all-weather, oil pollution detection system. The best detection of all oils tested in clear-weather conditions was by infrared scanners at 8-14 microns. Infrared scanners operating in 8-14 micron region of the spectrum produced imagery quality much superior to that produced in the 4-5.5 micron region. The 4-lens camera operating in the short wavelength visible and ultra-violet region shows the best detection capability of the photographic sensors. The 0.36-0.40 micron band produces the best contrast of all filters used. The effects of sun angle (glitter) degrades the detection capabilities of the longer wavelength bands. Visual color and infrared color photography appear to be equally capable of detecting oil on the surface of the water under the weather conditions experienced during performance of this program. Detection of oil slicks formed at spill rates of 0.05 gpm was possible immediately after

spillage. The small flow rate dispersed rapidly and was not discernible for extended periods of time. Color photographs in the visible portion of the spectrum were superior to the infrared in inferring flow rates by sensing a wider range of colors in the thicker slicks. Microwave radiometry is recommended as a backup detection mechanism to the infrared scanner in that it can provide an all-weather, day or night requirement. WRA modified.

B1. Barr, D. J. and W. P. James. 1975. Civil Engineering Applications of Remote Sensing. Transportation Engineering Journal 101:279-295.

An introduction to the concepts of remote sensing technology was presented. Remote sensor image interpretation was stressed as a practical tool for many civil engineering applications. The utility of remote sensing for use in the general areas of environmental and sanitary engineering, water resources, transportation engineering, geological engineering, and coastal engineering was described. References to publications dealing with specific remote sensing studies were keyed to general areas of application. The specific case of utilizing remote sensing for water quality studies was presented in detail. WRA

B2. Blanchard, B. J. and R. W. Leamer. 1973. Spectral Reflectance of Water Containing Suspended Sediment. In Remote Sensing and Water Resources Management; Proceedings of the Symposium, Burlington, Ontario, Canada, June 11-14, 1973, pp. 339-347. Urbana, Illinois: American Water Resources Association.

A spectral radiometer, measuring radiation in the visible and near-infrared portion of the spectrum, was used to examine (1) different concentration of red, black, and gray clay particles in water, and (2) several samples of natural pond water containing sediment. Four of the pond samples had algae present. Reflectance curves in the visible portion of the spectrum are sensitive to very low concentrations (less than 200 ppm suspended solids) of sediment with similar characteristics. The samples containing algae showed a good possibility of detecting algae by ratioing the reflectance near wavelength 570 nm with the reflectance at 680 nm. Response at 570 nm appears to be related to the suspended sediment. Results using film density measurements also show promise for use in estimating low sediment concentration. Author.

B3. Blanchard, B. J. and R. W. Leamer. 1973. Spectral Reflectance of Water Containing Suspended Sediment. In Remote Sensing and Water Resources Management, Proceedings No. 17, pp. 339-347. American Water Resources Association.

A spectral radiometer, measuring radiation in the visible and near-infrared portion of the spectrum, was used to examine (1) different concentrations of red, black, and gray clay particles in water, and (2) several samples of natural pond water containing sediment. Four of the pond samples had algae present. Density measurements were made of color and color infrared film photographs of the samples exposed at the same time as the radiometer measurements. Reflectance curves in the near-infrared region show very little change caused by changing sediment concentrations. However, reflectance curves in the visible portion of the spectrum are sensitive to very low concentrations (less than 200 ppm suspended solids) of sediment with similar characteristics. The samples containing algae showed a good possibility of detecting algae by ratioing the reflectance near wavelength 570 nm with the reflectance at 680 nm. Response at 570 nm appears to be related to the suspended sediment. Results using the film density measurements also show promise for use in estimating low sediment concentrations; however, the best combination of film and filter are not known for the different sediment characteristics. WRA

B4. Brereton, N. R. and R. A. Downing. 1975. Some Applications of Thermal Infrared Linescan in Water Resources Studies. Water Services 79:91-96.

The remote sensing method of thermal infra-red linescan has been applied in several regional studies concerned with the large scale development of groundwater resources. These studies were conducted to detect the location of groundwater discharges from the Chalk aquifer into the sea and to assess whether groundwater abstraction from a well field had any effect on vegetation or moisture content of the soil. Sewage outfalls with known temperatures and discharges were used as controls. The method is unlikely to detect spring discharges smaller than 100 liters/s. Groundwater discharges to rivers can be detected if the temperature difference between the surface water and the groundwater is sufficient to create a recognizable thermal anomaly or if groundwater discharge is high enough to not be diluted by the surface water too rapidly. While the thermal infra-red linescan method was not suitable for small or diffuse groundwater flow, the method is most applicable for detection of temperature anomalies in large expanses of water which cannot be economically surveyed from the ground. In coastal surveys, this technique may also be useful for studying the mixing of river and sea waters and for detecting pollution. WRA

B5. Bressette, W. E. and D. E. Lear, Jr. 1973. The Use of Near-Infrared Photography for Biodegradable Pollution Monitoring of Tidal Rivers. In Proceedings of the American Society of Photogrammetry, Fall Convention, pp. 906-926. Falls Church, Virginia: American Society of Photogrammetry.

On October 2, 1972, a pattern of chlorophyll a containing phytoplankton (algae) was detected from 3-km altitude in a series of near-infrared photographs of the Potomac River 'Salt Wedge Area.' Densitometer traces over the film images, related to in situ measurements of chlorophyll a concentrations that varied from 4 to more than 3000 micrograms/liter, revealed a phytoplankton 'bloom' threshold in the near infrared between the concentration of 34 and 51 micrograms/liter. The photography also revealed bottom features through two meters of water and made it possible to integrate chlorophyll a concentrations over a 16 sq km area to demonstrate this remote sensing technique for biodegradable pollution monitoring. Author.

B6. Burgess, F. J. and W. P. James. 1970. Aerial Photographic Tracing of Pulp Mill Effluent in Marine Waters. EPA-WQO Report 12040. 152 p.

Aerial photography taken of waste plumes from Kraft pulp mill ocean outfalls was shown to be an effective tool in the study of waste disposal sites. This technique is not limited by sea conditions and permits monitoring and evaluation of outfall sites throughout the year. Manpower requirements and costs for this method are considerably less than for conventional boat sampling surveys. Field studies were conducted on the waste plumes from Kraft pulp mill ocean outfalls at Newport and Gardiner, Oregon and Samoa, California. Waste concentrations were measured by conventional boat sampling techniques while aerial photography was taken of the outfall area from altitudes ranging from 3,000 to 11,000 feet. Computerized procedures were used to compute water currents, waste concentrations, toxicity zones and diffusion coefficients from the photography. The highest concentration measured directly over the outfalls was 2.3 percent waste by volume and the maximum influence with concentrations greater than 0.2 percent waste was 155 acres. Surface water current was found to be the dominant factor in the resulting plume pattern. During periods of low current velocities in the receiving water, the hydraulic head created by the effluent source was a significant factor in the resulting plume shape. Author modified.

C1. Catoe, C. E. 1971. The Applicability of Remote Sensor Techniques for Oil Slick Detection. Washington, D. C. Coast Guard: Office of Research and Development. 24 p. Available NTIS: AD-728422.

A wide variety of remote sensing techniques are briefly reviewed and their possible application to detection of oil slicks considered. Research is reviewed and field test results from oil spill overflights are presented. Considering

all available information, ultraviolet photographic techniques are considered to offer great potential for detecting oil spills. Other photographic techniques also lend themselves to this area. For example, infrared imagers and multispectral scanners are effective in the ultraviolet and blue spectra and at 8 to 14 micrometers. Radar and passive microwave techniques are also very promising. WRA

C2. Catoe, C. E. 1970. Results of Overflights of Chevron Oil Spill in Gulf of Mexico. Coast Guard, Washington, D. C.: Applied Technology Division. 19 p. Available NTIS: AD-714681.

The Chevron oil spill off the Louisiana coast in March 1970, was surveyed to investigate the potential of various remote sensing techniques for detecting and identifying oil slicks. Aerial photography (Color infrared, and ultraviolet) and infrared imagery were used during overflights of the spill. Color photography, because of the low contrast between oil and water, was effective only where the oil was quite thick. The color infrared photographs offered greater contrast between oil and water interface, with oil showing up as pink or red while water appeared blue. However, a certain amount of ambiguity appeared in these photographs in that sun glint and vegetation also gives a pink and red response. With UV sensitive film, the fluorescence coming from the oil was easily detected. Infrared imagery in the 8 to 14 micrometer region offered very good definition of oil due to its emissivity differences. WRA modified.

C3. Catoe, C. E. and F. L. Orthlieb. 1971. Remote Sensing of Oil Spills. In Proceedings of Joint Conference on Prevention and Control of Oil Spills, pp. 71-84. Washington, D. C.: American Petroleum Institute Publication.

The U. S. Coast Guard Office of Research and Development is currently engaged in basic and applied research to determine the feasibility of various remote sensing techniques for the detection and identification of oil slicks. To date, several remote detection techniques have shown promise for the detection and surveillance of oil slicks. Radar and passive microwave techniques appear very promising. Mapping experiments performed in the Chedabucto Bay area of Nova Scotia and in Southern California have resulted in synthetic aperture imagery in which oil slicks are quite evident and well defined. Using passive microwave techniques, it is possible to detect oil slicks on the open ocean. WRA modified.

C4. Chase, P. E. and W. Pettyjohn. 1973. ERTS-1 Investigation of Ecological Effects of Strip Mining in Eastern Ohio. In Symposium on Significant Results Obtained from the Earth Resources Technology Satellite-1. Vol. 1, pp. 561-568. Houston: NASA.

ERTS data were used to detect, map, and monitor the effects of strip mining. Enlarged ERTS imagery and statistically processed data (outline maps and imagery) of stripped earth and standing water were compared to aerial photos of a strip mine near Coshocton, Ohio. The outline maps and decision imagery may be used to form a disruption map of recently mined and underclaimed earth. WRA

C5. Conrod, A. C. and H. A. Short. 1968. Ocean Bottom Surveying with Aerial Photography. In Symposium on Earth Resources Aircraft Program, pp. 46A-1 to 46A-17. Houston: NASA.

Studies of the application of aerial photography and spectrography to ocean surveying show that good bottom detail may be obtained at depths ranging in some cases to more than 25 meters, and biological and geological features can be seen and interpreted. The method shows promise as a survey tool for examining the near-shore environment and in studying land-sea interactions, both natural and artificial. The kinds and amounts of suspended and dissolved water may be estimated with airborne radiometers. The uses of photography are compared with electro-optical imaging systems for possible operational use on ERSP and EROS satellites. Some of the design and application aspects of nonphotographic imaging systems are discussed. WRA

C6. Croy, R. L. and I. W. Nauman. 1970. Temperature and Water-quality Conditions of the Patuxent River Estuary, Maryland, January 1966 through December 1967. Chesapeake Science 11:199-209.

The effect of power plant cooling water in raising natural water temperatures at a location near the power plant on the Patuxent River estuary is clearly evident from thermograph records. Surface temperature at a station 333 m downstream from the discharge canal was raised an average of about 4 C, and at times by as much as 8 C. Temperature profiles obtained from airborne radiation equipment revealed a complicated surface temperature pattern and also showed the effects of density differences and wind action on the stream-electric station effluent plume. Turbidity levels were inversely related to salinity, with the highest annual mean of 28 Jackson Candle Units occurring in 1967, the lowest salinity year. The extreme tide range was 2.1 m; mean water levels at the Patuxent Bridge were highest in summer and lowest in winter. Water stages are more affected by wind speed and direction than by flow in the river. WRA modified.

D1. Davis, E. M. and W. J. Fosbury. 1973. Application of Selected Methods of Remote Sensing for Detecting Carbonaceous Water Pollution. In Remote Sensing and Water Resources Management; Proceedings of the Symposium, pp. 419-432. Urbana, Illinois: American Water Resources Association.

A reach of the Houston Ship Channel was investigated during three separate overflights correlated with ground truth sampling on the Channel. Samples were analyzed for such conventional parameters as biochemical oxygen demand, chemical oxygen demand, total organic carbon, total inorganic carbon, turbidity, chlorophyll, p^H, temperature, dissolved oxygen, and light penetration. Infrared analyses conducted on each sample included reflectance ATR analysis, carbon tetrachloride extraction of organics and subsequent scanning, and KBr evaporate analysis of CCl_4 extract concentrate. Imagery which was correlated with field and laboratory data developed from ground truth sampling included that obtained from aerial KA62 hardware, RC-8 metric camera systems, and the RS-14 infrared scanner. The images were subjected to analysis by three film density gradient interpretation units. Data were then analyzed for correlations between imagery interpretation as derived from the three instruments and laboratory infrared signatures and other pertinent field and laboratory analyses. Author

E1. Edgerton, A. and P. Hinds. 1971. Microwave Radiometric Observations of Controlled Oil Spills. In Remote Sensing of Southern California Oil Pollution Experiment, pp. 1-37. Coast Guard Office of Research and Development Report. Available NTIS: PB203 194.

During the fall of 1970, airborne microwave radiometric measurements of controlled oil spills were conducted off the Southern California Coast. Measurements were performed with dual-polarized 3.2- and 8.1- mm sensors utilizing forward antenna viewing angles of 45 degrees. Four sets of oil spills were performed to obtain passive microwave data on oil slicks over a variety of sea-surface conditions. Pollutants used for the tests included No. 2 diesel fuel, 26.1 and 21.6 API gravity crude oils, and 9.7 API gravity fuel oil. For each set of spills, ocean surface observations and airborne measurements were performed for three days, or until the slicks dissipated. Positive identification was made of oil slicks on the open ocean using microwave radiometry. Significant microwave brightness temperature oil slick signatures were noted for a wide range of ocean conditions (sea states 1-4) and oil film thickness (thicknesses less than 1 micron and greater). WRA

E2. Edgerton, A. T. and D. T. Trexler. 1969. Oceanographic Applications of Remote Sensing with Passive Microwave Techniques. In Proceedings of Sixth International Symposium of Remote Sensing of Environment, pp. 767-788. Ann Arbor: University of Michigan.

A useful tool for determination of sea state, sea ice, and pollution is passive remote sensing in the microwave spectral region. During aerial surveys of the Salton Sea, California and the North Atlantic Ocean, differences in radiometric brightness temperature of the sea surface was readily detected by scanning phased array radiometers. Sea State prediction by microwave brightness temperature, correlated with theoretical models for sea states less than 4 (beaufort). WRA

F1. Fisher, J. J. 1970. Criteria for Recognition of Estuarine Water Pollution by Aerial Remote Sensing. Technical Completion Report, Rhode Island Water Resources Center. 14 p. Available NTIS: PB-195 976.

Multispectral aerial photographic remote sensing analysis was made of water quality in estuarine areas. Photographic interpretation was compared with 'ground-truth' data. Four film emulsions proved most efficient; panchromatic, black and white infrared, color and color infrared. A simple inexpensive four camera system using these films was designed and developed for this study. WRA

F2. Fritz, N. L. 1970. The Use of Aerial Photography for Hydro-Biological Investigations. In Hydrobiology, 'Bioresources of Shallow Water Environments', Proceedings of Symposium, pp. 255-261. Urbana, Illinois: American Water Resources Association.

The characteristics, uses, and limitations of aerial photography are presented in the hope that hydrobiologists can use the information for their applications. A brief summary of many of the factors that affect aerial photography and its interpretation is included. Many of these factors are interdependent, and to obtain the optimum in information from a photographic system, a systems approach might be used in the selection of its individual elements. Many choices can be made between the various parameters, and the proper selection of each parameter can help maximize the usefulness of such photography. WRA modified.

F3. Funk, W. H. and D. C. Flaherty. 1972. The Use of Photography in Water Quality Research. Photographic Applications in Science, Technology and Medicine 7:20-22.

The first step in aerial photographic studies of lakes has been to make an aerial photographic survey of the particular lake or reservoir which has been scheduled for investigation. This helps to give the investigators a comprehensive picture of the lake environment in terms of its drainage basin, surface outlets, aquatic growth, possible nutrient sources and size in relation to other hydrographic features of the area. This initial aerial survey is followed by or conducted simultaneously with infrared photography of the lake and its environs. One of the characteristics of this material is that the chlorophyl of living algae and aquatic weeds is captured on the film in vivid pinkish red hues, whereas dead algae or vegetation exhibit a whitish or yellowish orange appearance. Aerial reconnaissance has made it possible to survey eight to ten lakes in a two-state area in a single day. On sampling trips, light penetration, water temperature, dissolved oxygen, p^H, alkalinity, and conductivity tests are made at various depths. Two-liter water samples are also collected for plankton and chemical analysis. A current project involving water quality surveillance is a study of 150 miles of the Lower Snake River drainage area located in southeastern Washington. Aerial photography shows that this stretch of the river is subjected to excessive runoff of topsoil shortly after the snow melts in the spring, and also during periods of high rainfall. WRA

G1. Goodell, H. G., C. M. Woolheater and K. L. Echternacht. 1972. Environmental Application of Remote Sensing Methods to Coastal Zone Land Use and Marine Resource Management. Geological Survey Interagency Report USGS-243. 132 p. Available NTIS: PB-214 547.

The potential of remote sensing both as a source of data and as the basis for an information system for resource analysis and management within the coastal zone is described. Criteria are presented for a computer based model for forecasting the environmental consequences of resource allocations involving land use decision. Its ultimate efficiency will depend on the accuracy of the algorithms which link land use to a specific environmental impact and on the identification of the synergistic effects of these impacts. Two major data sources are used: land use data as identified principally by remote sensing, and dynamic climatological data to be developed from the National Weather Records Center of NOAA. The demonstration project suggests the establishment of RICHEL, an environmental laboratory, wherein the impact algorithms initially used in forecasting could be verified by field data so that the precision of the algorithms could be refined. WRA

G2. Goolsby, A. D. 1971. Water Pollution Detection by Reflectance Measurements. In Joint Conference on Sensing of Environmental Pollutants, Palo Alto, California. American Institute of Aeronautics and Astronautics Paper.

The intensity of light reflected from various planar liquid surfaces has been measured. Results showed that the presence of a film of foreign material floating on a reference substrate can easily be detected by reflectance measurement if the two liquids contain significantly different refractive indices. The study of various optical configurations and the building and testing of a prototype monitoring device proves the method practical for application for continuous monitoring of water quality. WRA

G3. Gustafson, T. D. and M. S. Adams. 1973. Remote Sensing of Myriophyllum Spicatum L. in a Shallow, Eutrophic Lake. In Remote Sensing and Water Resources Management; Proceedings of the Symposium, Burlington, Ontario, Canada, June 11-14, 1973, pp. 387-391. Urbana, Illinois: American Water Resources Association.

An aerial 35 mm system was used for the acquisition of vertical color and color infrared imagery of the submergent aquatic macrophytes of Lake Wingra, Wisconsin. A method of photographic interpretation of stem density classes is tested for its ability to make standing crop biomass estimates of Myriophyllum spicatum. The results of film image density analysis are significantly correlated with stem densities and standing crop biomass of Myriophyllum and with the biomass of Oedogonium mats. Photographic methods are contrasted with conventional harvest procedures for efficiency and accuracy. Author

G4. Guy, H. P. 1974. Remote Sensing Techniques for Evaluation of Urban Erosion and Sedimentation. In Effects of Man on the Interface of the Hydrological Cycle with the Physical Environment; Proceedings of Paris Symposium, pp. 145-149. International Association of Hydrological Sciences Publication No. 113.

Low-altitude aerial photography was used to supplement ground-based measurements for the evaluation of erosion and sedimentation conditions during the construction of a large office complex at Reston, Virginia. Ground measurements included precipitation, runoff, and sediment, as well as selected measurement of sheet erosion, rill development and sediment deposition. Satellite imagery could not be used because of detail loss upon the required enlargement. Low-altitude photography (scale 1:3600) gave good delineation of land-use changes. If used within a few hours of a rainstorm, low-altitude photography provided information on

erosion and sedimentation features resulting from the storm. Ground-based measurements were necessary to define the timing and magnitude of the erosion and deposition processes. WRA modified.

H1. Holter, M. R. 1970. Optical (Infrared and Ultraviolet-visual) Remote Sensing of Pollution of Water Bodies. In IEEE International Conference on Engineering in the Ocean Environment, pp. 45-50. Ann Arbor: University of Michigan.

Experimental results on developing means of remotely sensing material and thermal pollution in various water bodies are presented. These methods of detection and identification of pollutants are described in detail. The results also suggest possibilities of sensing and calculating wave height and motion, subsurface solid features, bottom depths, turbidity and sediment loads. WRA

H2. Horvath, R. and S. R. Stewart. 1971. Analysis of Multispectral Data from the California Oil Experiment of October 1970. In Remote Sensing of Southern California Oil Pollution Experiment. (Coast Guard Office of Research and Development Report). pp. 91-107. Washington, D. C. Available NTIS: PB-203 194.

The multispectral equipment on The University of Michigan's C-47 aircraft acquired calibrated, optical, remote-sensor data from a controlled oil-spill exercise during October 1970. The spill was located in Pacific coastal waters between Annacapa Island and Santa Barbara Island, California. Four discrete slicks were produced with 330 gallons each of 9.7 API gravity fuel oil, 21.6 API gravity crude oil, 26.1 API gravity crude oil, and No. 2 diesel oil. Multispectral line-scanner data were acquired in 17 spectral bands between the wavelengths of 0.32 and 11.7 millimicrons. Additional aerial photographic data were acquired on panchromatic, normal color, and infrared false-color films. Using index of refraction, scattering and absorption coefficients measured in the laboratory, a mathematical reflectance model for oil on water was used to generate values of radiance from each of the four oils and from water as a function of thickness. The 9.7 API residual fuel exhibited a strange spatial pattern compared to the others after several hours on the water's surface. WRA

J1. James, W. P. 1971. Quantitative Evaluation of Water Quality in the Coastal Zone by Remote Sensing. College Station: Texas A & M University Remote Sensing Center. 67 p.

Remote sensing can be a valuable tool for a program used to control the quality of water in an estuary. By monitoring both the pollution sources and the environmental quality the

interactions between the components of the estuarine system can be better understood. Remote sensing can provide comprehensive quantitative water quality data of a large area. Variations in light return from the water column can be quantitatively related to water quality parameters. Thus, remote sensing can be used to detect pollution sources, map the zone of influence of the waste source and the water quality, and determine waste disposal design parameters such as diffusion coefficients and circulation patterns. Many of the surface changes in vegetative patterns and density caused by extended exposure to low waste concentration might be detected by a continuous monitoring program. By understanding the response of the environment to various waste loadings, the effects of additional pollution can be predicted and degradation of the water quality prevented by prior waste management decisions. WRA modified.

K1. Keafer, Jr., L. S. and L. P. Kopia. 1973. Development of Flight Experiments for Remote Measurement of Pollution. In Remote Sensing of Earth Resources; Proceedings of the Second Conference on Earth Resources Observation and Information Analysis System. Vol. 2, pp. 129-163. Tullahoma: University of Tennessee.

The status as of February 1973 of several NASA-sponsored development projects is reported concerning flight experiments for remote measurement of pollution. Eight passive multispectral instruments for remotely sensing air and water pollutants are described, as well as two active (laser radar) measuring techniques. These techniques are expected to add some new dimensions to the remote sensing of water quality, oceanographic parameters, and earth resources. Multiple applications in these fields are generally possible. Successful completion of the flight demonstration tests and comparisons with simultaneously obtained surface truth measurements may establish these techniques as valid water quality monitoring tools. IAA

K2. Kennedy, J. M. and E. G. Wermund. 1971. The Behavior of Oil on Water Derived from Airborne Infrared and Microwave Radiometric Measurements. In Proceedings of Joint Conference on Prevention and Control of Oil Spills, pp. 469-477. Washington, D. C.: American Petroleum Institute Publication.

Physical properties of oil spills are described, and both infrared imagery and microwave radiometry for tracking and calculating volumes of oil spilled are evaluated. Infrared and microwave methods can effectively operate under day/night and relatively bad weather conditions. These two systems, when operated together, can be used to locate, track, and determine the volume of oil on sea surfaces. In

cases of flowing spills, fair estimates of flow rates and the effectiveness of clean up operations can be determined. Also, the temporal image (IR) pattern change can be used to forecast and hindcast surface movements of spills. WRA

K3. Kiefer, R. W. and J. P. Scherz. 1971. Aerial Photography for Water Resources Studies. Journal of the Surveying and Mapping Division, ASCE, Proceedings (Paper 8545). 97:321-333.

The fundamentals of color and color-infrared photography are reviewed. Illustrations are presented to show the use of color and color-infrared aerial photography to study siltation and algae growth in lakes, to map aquatic plants in lakes, to detect and monitor water pollution, and to study stream flooding. WRA

K4. Klemas, V., et al. 1973. Satellite Studies of Turbidity and Circulation Patterns in Delaware Bay. In Proceedings of the American Society of Photogrammetry, Fall Convention, pp. 848-871. Falls Church, Virginia: American Society of Photogrammetry.

Satellite imagery from four successful ERTS-1 passes over Delaware Bay during different portions of the tidal cycle are interpreted with special emphasis on visibility of suspended sediment and its use as a natural tracer for gross circulation patterns. The MSS red band (band 5) appears to give the best contrast, although the sediment patterns are represented by only a few neighboring shades of grey. Color density slicing improves the differentiation of turbidity levels. However, color additive enhancements are of limited value since most of the information is in a single color band. The ability of ERTS-1 to present a synoptic view of the surface circulation over the entire bay is shown to be a valuable and unique contribution of ERTS-1 to coastal oceanography. Author

K5. Klemas, V. 1971. Detecting Oil on Water: A Comparison of Known Techniques. In Joint Conference on Sensing of Environmental Pollutants, Palo Alto, California, 6 p. American Institute of Aeronautics and Astronautics Paper No. 71-1068.

New developments in oil pollution detection are reviewed. Available techniques are compared according to their effectiveness. Remote sensing and in situ techniques, with a potential for real-time, automated operation are emphasized. Included in the review are a floating capacitor, floating reflectometer, absorption spectrometry, fluoremetry, reflectance photography, thermal infrared imagery, microwave radiometry, radar and micro-balance. WRA

K6. Klooster, S. A. and J. P. Scherz. 1973. Water Quality Determination by Photographic Analysis. In Remote Sensing of Earth Resources; Proceedings of the Second Conference on Earth Resources Observation and Information Analysis System. Vol. 2, pp. 1187-1200. Tullahoma: University of Tennessee.

The combination of field data and a laboratory analysis of paper mill wastes has led to a positive correlation between optical densities on film and turbidity in water. The turbidity can be correlated with total suspended solids if the constituent parts of the effluent remain the same and the volumetric flow remains relatively constant. The described technique requires the use of a monochromator for the selection of the bandwidths containing the most information. IAA

L1. Lane, R. K. 1970. Great Lakes Thermal Studies Using Infrared Imagery. Limnology and Oceanography 15:296-300.

During spring to autumn, 1968, seven airborne surveys of western Lake Ontario were made with an infrared scanner. The sensor of the infrared scanner repeatedly scans a path normal to flight across a 120 deg field of view detecting electromagnetic radiation in the 8-14 micron band. Spatial resolution is 16 m radians and thermal resolution is estimated at 0.01C. Examples of mosaics of infrared imagery of the western end of Lake Ontario are used to demonstrate their value in revealing detailed surface thermal patterns. Additional data from airborne thermometry and shipboard measurements confirm the interpretation of large scale dynamic processes. Smaller scale phenomena such as internal wave patterns and small eddies, are also interpretable. WRA modified.

L2. Lane, R. K. 1970. Photography and Other Remote Sensing of Water Pollution. Water Pollution Control 108:20-21.

Photography has long been used as a remote sensing tool for environmental data collection from aircraft. In water pollution studies most interest is centered around the need for observing the behavior of effluents which introduce pollutants to rivers or lakes. Qualitative examinations of effluents through photography can be useful to locate effluents, to determine how their behavior is affected by local characteristics, ambient flow rates, and meteorological conditions, and to determine relative intensities of discharges. Techniques for quantitative assessments of polluted discharges are not yet operationally effective. WRA

L3. Leachtenauer, J., et al. 1972. Natural Resource Information System Remote Sensing Studies. Boeing Computer Services, Inc., Seattle, Washington. 110 p. Available NTIS: PB211 384.

A major design objective of the Natural Resources Information System entailed the use of remote sensing data as an input to the system. In the area of water resources and hydrology a great number of applications of remote sensing have been tested. These include studying drainage patterns where detailed map coverage is lacking; taking a census of water resource features, both natural and man-made, such as springs, wells, ponds, detentions, diversions, and canals; studying water quality in terms of industrial, mining or agricultural pollutants; and analyzing regional geomorphology in order to understand the groundwater and surface water regimes. WRA modified.

L4. Lind, A. O. 1973. Application of ERTS-1 Imagery in the Vermont-New York Disputs Over Pollution of Lake Champlain. Burlington: Remote Sensing Laboratory, Vermont University. 5 p. Available NTIS: N74-11183.

Three ERTS-1 images from different dates were used to document the effluent pattern in Lake Champlain emanating from the large paper mill north of Fort Ticonderoga, New York. A composite map shows the plume. The State of Vermont is currently suing both the International Paper Company and the State of New York for degrading the waters of Lake Champlain in Vermont. Vermont proposed that the map and the enlarged reproductions of ERTS imagery be entered in evidence. The special U. S. Supreme Court Master accepted the ERTS imagery and the ERTS-derived information in evidence. This is the first time that satellite imagery and satellite-derived information have been used as evidence in a court of law. WRA

L5. Lind, A. O., E. B. Henson and J. Pelton. 1973. Environmental Study of ERTS-1 Imagery: Lake Champlain and Vermont. In Symposium on Significant Results Obtained from the Earth Resources Technology Satellite-1: Vol. 1 - Technical Presentations, pp. 643-650. Houston: NASA.

Industrial water pollution and turbidity in Lake Champlain were identified and mapped using ERTS data. ERTS imagery also provides a foundation for revising land use inventories which will be necessary for meeting some of the informational needs of the Land Use and Land Capability Act (Act 250). Major classes of land use were identified and mapped, and substantial progress was made toward the mapping of such land use divisions as crop and forest type and wetlands. WRA

L6. Lindgren, D. T. 1971. Color Infrared (CIR) Photography: A Tool for Environmental Analysis. Hanover, New Hampshire: Department of Geography, Dartmouth College. 42 p. Available NTIS: PB-204 472.

The nature of color infrared film (CIR), its capabilities and limitations, are described and its potential as a tool in environmental studies is discussed. Included is a section on the use of CIR in water quality analysis. The growth of algae is easily detected by this technique, which can be used as an indicator of undesirable conditions. In treatment facilities, CIR has been used to identify trickling filters that are overloaded since they reflect greater amounts of infrared than those that are operating efficiently. CIR can also be used to determine the degree of oil spills, CIR has not proven as reliable as other types of film because of its sensitivity to sun angles. Finally, CIR can be used for dead-fish counts where some toxic substance has been released in the water. WRA

L7. Link, L. E. and A. Shindala. 1973. Utilization of Remote Sensing in River Basin Studies. Water Resources Bulletin 9:901-907.

Remote sensing techniques have the potential for significantly reducing the level of effort in a river basin water quality study. A general methodology is proposed for conduct of river basin water quality studies. The primary advantage is rapid evaluation of the water quality conditions of a river basin. Remote sensing techniques are a fundamental part of the methodology. The proposed methodology consists of two phases. Phase I deals with the study of the water resource characteristics of the basin as a system and identification of 'critical areas'. Phase II of the methodology involves the detailed study of the critical areas by means of computerized water quality simulation models. WRA

L8. Lowe, D. S. 1970. Infrared and Multispectral Sensing in Hydrobiological Applications. In Hydrobiology, 'Bioresources of Shallow Water Environments,' Proceedings of Symposium, pp. 262-273. Urbana, Illinois: American Resources Association.

Optical-mechanical scanners can be used in hydrobiological investigations to generate imagery significantly different from that produced by cameras. Infrared imagery contains information directly related to surface temperature of features. Multispectral scanners and data processors analyze the spectral characteristics of each element in a scene and can identify areas of similar spectral characteristics. In some applications, terrain features have been successfully classified on the basis of their spectral properties. Such automated classification is ideally suited for large area coverage. WRA

L9. Lundquist, E. 1973. Applied Remote Sensing of Water Pollution. In Remote Sensing of Earth Resources; Proceedings of the Second Conference on Earth Resources Observation and Information Analysis System, pp. 1121-1135. Tullahoma: University of Tennessee.

For effective management of water resources there is an urgent need for reliable synoptic information of the water conditions in whole aquatic systems. This paper deals with an aerial continous strip multiband photographic system that provides new, often unique advantages for acquisition and processing of data having significance in water pollution control. By use of narrower spectral bands, as low as abcut 1 nanometer, than heretofore possible in conventional multispectral photography, detection and measurement of dissolved and suspended substances can be accomplished both quantitatively and qualitatively. Author modified.

M1. McCauley, J. R. 1974. Skylab Study of Water Quality. Lawrence: University of Kansas. 9 p. Available NTIS: N74-32764.

Earth Resources Environmental Program (EREP) data products thus far received for the September 18, 1973, SL3 pass over southeast Kansas include S-190A positive transparencies. These photos cover three lakes: Toronto, Fall River, and Elk City Reservoirs. Concurrent with satellite overflight, field crews were on all three lakes collecting water samples. These samples were analyzed for concentrations of bicarbonate, carbonate, calcium, magnesium, potassium, sodium, sulfate, and chloride. In addition, total solids, total heat-stable solids, suspended solids, heat-stable suspended solids, and pH were determined. The four black and white S-190A products were analyzed quantitatively with a Macbeth EP-1000 macrodensitometer. Five locations were selected on Fall River and Toronto Reservoirs, and four on Elk City Reservoir. Each density measurement was centered as nearly as possible over one or more ground truth sampling station. Attempts were then made to relate film density to corresponding water quality parameters. The analysis established a strong linear correlation between the red/green radiance ratio and suspended solids. This result compared quite favorable to ERTS MSS CCT results. WRA

M2. McElroy, A. D., et al. 1975. Water Pollution from Nonpoint Sources. Water Research 9:675-681.

The nature and extent of nonpoint pollution sources in the United States were assessed for four major industrial activities: agriculture, silviculture, mining and construction. Nonpoint pollutants exert a significant influence on water quality in the United States. Based on land use

data, more than 97% of the land area in the U. S. is a potential source of nonpoint pollution. Among the pollutants identified from agriculture, silviculture, mining and construction, important pollutants are sediment, nutrients, pesticides, organic wastes, thermal discharges, acid mine drainage, salinity, radioactivity, microbial pollutants, and heavy metals. Agriculture, especially cropland, is responsible for the release of large quantities of sediment, nutrients, and pesticides. Because of the production of large quantities of organic wastes from livestock operations, these wastes can be potential sources of water quality degradation, if not handled properly. Silviculture is a source of sediment. Other pollutants originating from silvicultural operations include very limited quantities of nutrients, pesticides, and thermal discharges. Surface mining is a major source of erosion sediment. Acid mine drainage, salinity, and heavy metals are other important pollutants from mining. Sediment is a major pollutant from construction industry. WRA

M3. Mairs, R. L., et al. 1973. Application of ERTS-1 Data to the Protection and Management of New Jersey's Coastal Environment. In Symposium on Significant Results Obtained from the Earth Resources Technology Satellite-1: Vol. 1 - Technical Presentations, pp. 629-634. Houston: NASA.

ERTS-1 imagery is being used by the New Jersey Department of Environmental Protection to develop information that will assist the state in managing its coastal resources. Initial analyses of imagery from several successive ERTS-1 orbits show the extent, predominant drift, and dispersion characteristics of waste disposal in coastal New Jersey waters. Imagery (MSS bands 4 and 5) for several orbits shows the New York Harbor tidal discharge extending as far south as Long Branch, New Jersey. Increased reflectance of turbid waters shows the effects of a large sewage effluent flow. As these waters are flushed with each tidal change, the turbid waters emanate out to the populous bathing beaches. WRA

M4. Malin, Jr., H. M. 1971. Pollution Detection by Remote Sensing. Environmental Science and Technology 15:676-677.

Of critical importance is a global monitoring system--a data-gathering network that will provide a base from which to assess the effects of changing pollutant concentrations, climatological patterns, and demographic shifts on the environment. The Aeronautics and Space Administration (NASA) and the U. S. Geological Survey (USGS) are collaborating on a limited-scale remote sensing venture called CARETS (Central Atlantic Regional Ecological Test Site). Early next year, NASA plans to launch its Earth Resources Technology Satellite (ERTS) for the collection of remote data

on a much larger scale. Then, in 1973, Skylab will provide additional data, perhaps on a global basis. Ultimately, the data will be fed into the Department of Interior's Earth Resources Observation System (EROS) which is administered by USGS; the EROS data center is located at Sioux Falls, South Dakota. WRA

M5. Millard, J. P. and J. D. Arvesen. 1971. Results of Airborne Measurements to Detect Oil Spills by Reflected Sunlight. In Remote Sensing of Southern California Oil Pollution Experiment. (Coast Guard Office of Research and Development Report). pp. 38-62. Washington, D. C. Available NTIS: PB-203 194.

Airborne measurements were made over controlled oil-spill test sites to evaluate various radiometric techniques for detecting oil on water. The techniques consisted of absolute radiometry, differential radiometry and polarimetry. All of the techniques were based on measuring the contrast of sunlight reflected or backscattered by oil and water. The instrumentation consisted of a spectroradiometer, which measured spectral radiance over the wavelength range 380 to 950 nm, and a differential radiometer, which measured the difference in radiance between two wavelength bands or two polarization components. The instruments viewed in the nadir direction. The results of these measurements show that (1) maximum contrast between oil and water is in the ultraviolet and red portions of the spectrum; (2) minimum contrast is in the blue-green; (3) differential polarization appears to be a very promising technique; (4) no characteristic absorption bands, which would permit one oil to be distinguished from another, were discovered in the spectral regions measured; (5) sky conditions greatly influence the contrast between oil and water; and (6) highest contrast was achieved under overcast-sky conditions. WRA

M6. Mitsch, W. J. 1973. Remote Sensing of Water Quality: A State of the Art Report. Gainesville: Florida Water Resources Research Center. 14 p. Available NTIS: PB-223 503.

Remote sensing, or the carrying out of aerial or space surveys of the earth's surface, is finding several applications in the fields of water quality and water resource management. It offers a means of obtaining large amounts of data, but its value is in the expansion of data in the spatial, temporal and spectral modes. The most valuable techniques presently are photography, infrared scanning and multispectral scanning. Aircraft applications include the measuring of the distribution of various waste discharges into water bodies and the study of aquatic plant growth and benthic communities. The ERTS (Earth Resources Technology Satellite) program of the U. S. Department of the

Interior is investigating satellite applications of monitoring the earth's resources. The water resource applications are less obvious than those of the aircraft and concern environmental indicators on a much larger scale. However, the satellite offers the enchancement of data in the temporal mode with periodic remote sensing of most of the earth's surface. WRA

N1. National Field Investigations Center. 1972. Remote Sensing Report, Galveston Bay, Houston Ship Channel, Trinity Bay, Houston, Texas for February 1972. Denver, Colorado. 51 p. Available NTIS: PB-230 339.

An aerial remote sensing program was conducted approximately twice each month from February 1972 to January 1973. Areas covered included: Houston Ship Channel from the Turning Basin at Buffalo Bay to Morgan Point, Galveston Bay from Morgan Point to the Gulf of Mexico, and Trinity Bay in vicinity of the Houston Lighting and Power Company cooling water canal discharge. The purpose of aerial reconnaissance was to provide: (1) industrial outfall trend data, (2) data regarding presence and sources of oil pollution in the Houston Ship Channel, and (3) data regarding presence of thermal pollution in Trinity Bay. All industrial discharges present at flight time were recorded and identified to the extent possible. The presence of oil on the Channel waters was significantly less than that recorded during 3 July 1971 flights. Many industrial outfalls have been present during the total of 4 missions. As always, the discharges from 7 industrial complexes were present. The septic tendencies of the Channel waters had improved negligibly from July 1971 flights. The turbidity levels in the upper reaches of Galveston Bay were quite high at the time of the February 1972 flight. This was felt to have been partially caused by the southeasterly winds present at that time. The behavior of the Houston Lighting and Power Company's thermal discharge was effectively documented, and relative temperature levels and plume dispersion patterns were shown. WRA

N2. National Field Investigations Center. 1972. Remote Sensing Report: Major Waterways, Memphis, Tennessee Vicinity. Denver, Colorado. Available NTIS: PB-230 431.

A second aerial remote sensing reconnaissance mission was flown over Memphis on February 17, 1972. The timing of this mission coincided with field operations of a ground-survey team studying the following five waterways: (1) Nonconnah Creek, (2) Wolf River, (3) Loosahatchie River, (4) McKellar Lake, (5) Mississippi River, from a point adjacent to Beef Island downstream approximately to the

Tennessee/Mississippi State Line. Twenty-eight outfalls and drainage ditches were identified in the airborne imagery recorded. At the time of imaging, these 28 sites showed sufficient indications that they were or had the potential of introducing polluted effluence into the five waterways. The most significant effluent in the area appeared to be that of nearly raw sewage. Numerous ditches throughout the target area appeared to serve only as natural drainage. WRA modified.

P1. Piech, K. R. and J. E. Walker. 1971. Aerial Color Analyses of Water Quality. Journal of Surveying and Mapping Division, ASCE Proceedings (Paper 8507). 97:185-197.

A new technique utilizing color photography in aerial water analyses uses natural objects in the photographic image to remove peripheral effects in the water quality measurement. The color of a body of water depends upon: (1) source effects, (2) atmospheric effects, (3) surface reflection effects, and (4) volume effects. Volume spectral reflectance is the only definition of water color sensitive to water quality. All other color effects are peripheral effects, and can be described by three parameters. Crucial to the technique is use of shadow information; information traditionally of limited value to the photointerpreter. The technique is applied to measurement of chlorophyll content in Lake Chautauque in New York State. Reflectances of ground objects are in excellent agreement with aerial data. WRA

P2. Pilon, R. O. and C. G. Purves. 1971. Radar Detection and Monitoring of Oil Slicks. In Remote Sensing of Southern California Oil Pollution Experiment. (Coast Guard Office of Research and Development Report). pp. 63-90. Washington, D. C. Available NTIS: PB-203 194.

The Naval Research Laboratory participated in a joint agency controlled oil slick experiment in the Pacific Ocean, sponsored by the United States Coast Guard in the Fall of 1970. Radar imagery of the oil slicks, on vertical polarization, was obtained at frequencies of 428 MHz, 1228 MHz, 4455 MHz, and 8910 MHz during low sea state conditions. At frequencies of 1228 MHz and higher, the slicks were depicted with sharp boundaries. At 428 MHz, the boundaries were indistinct. Approximately 100 gallons of oil were detected as it was being discharged from the generating ship and similar spills were mapped from the initial thickness to equilibrium thicknesses of 1 micron or less. Thin streamers of oil and wind blown films were also imaged. Area growth rates were obtained for 660 gallons spills of API 26.1 crude oil and API 9.7 fuel oil on a calm sea. WRA

P3. Polcyn, C. and D. R. Lyzenga. 1973. Multispectral Sensing of Water Parameters. In Remote Sensing and Water Resources Management; Proceedings of the Symposium, Burlington, Ontario, Canada, June 11-14, 1973, pp. 394-403. Urbana, Illinois: American Water Resources Association.

With the development of the multispectral scanner, improved techniques for mapping temperature gradients, turbidity, water color, and alga concentrations over large areas have been demonstrated. Where lake water transparency is sufficiently clear to detect light reflections from the lake floor, a remote calculation of water depth is possible. Examples of the mapping of the thermal bar in Lake Michigan, river discharges, and the nearshore environment are shown. Author modified.

P4. Pollution Control Branch, U. S. Coast Guard. 1971. Remote Sensing of Southern California Oil Pollution Experiment. Washington, D. C.: U. S. Coast Guard. 107 p. Available NTIS: PB-203 194.

The Coast Guard conducted a controlled oil spill test off the Coast of Southern California in October 1970 to evaluate the performance of several remote sensing techniques which show promise in the detection and surveillance of oil slicks. These techniques were utilized in a series of airborne measurements of small controlled oil spills. The general objectives were to gather multispectral signature data for oil, to determine which techniques are useful for surveillance and detection of slicks; and to assess from the remote sensing imagery and ground truth data (sea state, winds, currents, type of oil, etc.) the spreading rate and distribution of oil slicks on the sea. The results and findings from these participants are included as four separate papers. WRA modified.

P5. Pluhowski, E. J. 1973. Remote Sensing of Turbidity Plumes in Lake Ontario. In Symposium on Significant Results Obtained from the Earth Resources Technology Satellite-1. Vol. 1, pp. 837-846. Houston: NASA.

Preliminary analyses of ERTS-1 imagery demonstrates the utility of the satellite to monitor turbidity plumes generated by the Welland Canal, and the Genesee and Oswego Rivers. Although visible in high altitude photographs, the Niagara River plume is not readily identifiable from satellite imagery. WRA

R1. Rudder, C. L., A. G. Wallace and C. J. Reinheimer. 1973. Aerial Detection of Spill Sources. Environmental Protection Agency, Technology Series Report, EPA-R2-73-289. 23 p. Available NTIS: PB-228 105 (microfiche) or from GPO as EPI 2312:73-289.

An imagery interpretation key of the petroleum industry was developed for use with an aerial surveillance spill prevention system. Aerial baseline and stereogram photographs as well as aerial multiband, aerial oblique, and ground photographs of oil refineries were obtained for inclusion in the key. Processing systems to convert crude oil to fuel and LPG, gasoline, heavy fuel oils, lubricating oils and asphalt were identified with the help of military oil refinery interpretation keys. Three petro-chemical facilities within the refinery were also located and identified. The identification of potential spill sources as related to processing systems, product storage and disposition of by-products and waste was performed. The results were confirmed by refinery personnel and included in the oil refinery key. Concurrent with the flight program, fifteen samples of spilled material were obtained along with the appropriate ground truth data. Chemical and spectral analyses of the samples were performed and correlated with the multiband image analysis. Finally the use of aerial photography for temporal change detection was evaluated and included in the appropriate sections of the key. WRA

R2. Ryan, P. J., K. D. Stolzenbach and R. A. Elder. 1973. Water Temperature Monitoring by Thermal Scanning. In Remote Sensing of Earth Resources; Proceedings of the Second Conference on Earth Resources Observation and Information Analysis System, pp. 1137-1145. Tullahoma: University of Tennessee.

Airborne thermal infrared detection has become a popular water temperature survey technique because it has the potential to provide the required synoptic coverage. The factors affecting the qualitative and quantitative nature of such surveys are discussed. Emphasis is on the difficulties of determining subsurface temperature from surface measurements rather than on the effects of reflected sky radiation and atmospheric attenuation. It is considered that errors in the determination of water temperature may be reduced, but not eliminated by applying computed or observed corrections. IAA

S1. Salomonson, V. V. 1973. Water Resources. In Symposium on Significant Results Obtained from Earth Resources Technology Satellite-1. Vol. III, pp. 57-69. Greenbelt, Maryland: Goddard Space Flight Center, NASA.

Various land uses related to water resources management can easily be identified and mapped using ERTS-1 data at a scale of 1:250,000. The sources of water pollution, sediment load sources, and changing water yield can be delineated. ERTS-1 detection of geologic fracture zones and especially intersections of fractures has potential for the development of groundwater resources. Areas inundated by flooding can be mapped at scales of 1:250,000 or larger. WRA modified.

S2. Scarpace, F. L. and T. Green, III. 1972. The Use of a Thermal Line Scanner in the Remote Sensing of Water Pollution. Wisconsin University Sea Grant Program Technical Report No. 13. 11 p. Available NTIS: COM-72-10121.

Remote sensing of surface parameters of water bodies was used to study pollution sources on the Fox River in Neenah-Menasha, the Point Beach Power-plant located on Lake Michigan, and a section of the western coastal zone of Lake Michigan. The Neenah-Menasha plant is a municipal sewage treatment plant which handles approximately twenty million gallons of sewage per day for the cities of Neenah and Menasha, Wisconsin. Stagnant water lies at the bend in the river on the near downstream side of the outfalls. Here a proliferation of green algae exists that feed off the treated sewage. The visible portion of this pollutant was recorded on 35 mm color and 35 mm color IR film. The Point Beach Nuclear Powerplant is located on Lake Michigan approximately 5 miles north of Two Rivers, Wisconsin. The imagery from the thermal line scanner shows the thermal structure of the plume. The temperature at the intake was 16.4 deg C; the temperature at the outfall was 25.7 deg C. Thermal imagery of the powerplant on the western coastal zone of Lake Michigan shows relatively sharp demarcation between the cold water near shore and warmer offshore water. WRA

S3. Scherz, J. P. 1971. Monitoring Water Pollution by Remote Sensing. Journal of Surveying and Mapping Division, ASCE Proceedings (Paper 8550). 97:307-320.

Imaging remote sensing techniques can be effectively utilized as a water pollution monitoring tool if the advantages of imaging remote sensing as applied to other fields are understood as well as how electromagnetic energy reacts with water. The advantages of imaging remote sensing techniques are that: (1) They provide an overall view at one instant of time; (2) they provide a detailed time record which provides means of detecting changes with time; and (3) they can expand the limits of the human eye and sense where the eye cannot see. Short wavelengths of UV and blue energy reflect from the surface without much penetration, while green energy penetrates to a maximum extent, and IR energy is absorbed by only a few inches of water. WRA

S4. Scherz, J. P. 1971. Remote Sensing Considerations for Water Quality Monitoring. In Proceedings of the 7th International Symposium on Remote Sensing of Environment. Ann Arbor: Willow Run Laboratory, University of Michigan.

Remote sensing is a monitoring tool for water pollution control. There is one major difference however, between applying remote sensing to water monitoring as compared to applying it in other areas, that difference being how electromagnetic energy reacts with the wastes and water. Various wavelengths of the energy spectrum react in different ways with water. Short UV energy is reflected directly from the surface; some visible wavelengths penetrate quite well into the water and return from the bottom; and the longer IR wavelengths are completely absorbed. Some wavelengths are reflected at the surface and other wavelengths go deeper and return, while others do not return at all. There is a depth penetration consideration necessary in water quality monitoring which must be taken into account before proper interpretationkeys can be made up and effectively utilized. WRA modified.

S5. Scherz, J. P., J. F. Van Domelen and S. A. Klooster. 1973. Aerial and Satellite Photography - a Valuable Tool for Water Quality Investigations. In Proceedings of the American Society of Photogrammetry, Fall Convention, Part 2, pp. 883-905. Falls Church, Virginia: American Society of Photogrammetry.

An investigation of surface, volume, and bottom effects in Lake Superior is conducted. The objective of the reported study is the development of a reliable technique for the monitoring and the quantification of the water quality parameters associated with volume reflectance. Basic relationships are discussed together with details concerning the equipment used in the studies, the water quality on the basis of aerial photos and satellite imagery, and the effects of oil on sky-light reflection. IAA

S6. Schubert, J. S. and N. H. MacLeod. 1973. Digital Analysis of Potomac River Basin ERTS Imagery: Sedimentation Levels at the Potomac-Anacostia Confluence and Strip Mining in Allegheny County, Maryland. In Symposium on Significant Results Obtained from the Earth Resources Technology Satellite-1. Vol. 1, pp. 659-664. Houston: NASA.

Two simple algorithms for classification of sedimentation levels in water and for delineation of active strip mines are used with ERTS data for sedimentation analysis of the Anacostia River, the Potomac River, and mud flats resulting from effluent of a major sewage treatment plant. Mud flats of

organic or mineral origin are easily distinguished. Several classes of sedimentation are easily constructed. The mines are cut into the horizontal contour of the valley slopes and are easily distinguished from their surroundings. WRA modified.

S7. Smith, A. F., et al. 1974. Environmental Observations of the Great Salt Lake Basin from ERTS-1. In Conference on Aerospace and Aeronautical Meteorology, 6th, El Paso, Texas, pp. 49-52. Boston, Massachusetts: American Meteorological Society.

Some ERTS-1 observations of snowcover, turbidity variations in the major lakes, surface water area changes, land use features, and phenomena associated with industrial emissions are described. Turbidity patterns in the major water bodies can be observed that appear to be related to the general wind flow, or to lake circulation patterns, and the chemical or biological constituents in the water. Monthly, seasonal, and annual changes in surface water extent can be monitored and serve as indicators of water availability. Time and space variations in snowcover that are a function of exposure or time of year were observed in some regions. Specific measurements of snowline altitude during the major snowmelt period of 1973 were obtained. The existence and effect of industrial emission on vegetation were found to be detectable.

T1. Thompson, D. E., et al. 1973. Seasonal Aspects of Remote Sensing Coastal Resources. In Remote Sensing of Earth Resources; Proceedings of the Second Conference on Earth Resources Observation and Information Analysis System. Vol. 2, pp. 1201-1249. Tullahoma: University of Tennessee.

The application of remote sensing technology to environmental problems in the southeastern coastal zone was studies on the Georgia coast where missions were flown six times during the year. The effect of season and meteorological variables was considered in relation to information needed from the remote sensing missions. Coastal resources including the highly productive salt marshes; shell and sand deposits; timber; and water were evaluated via remote sensors using aerial color, color infrared, black and white, and black and white infrared photography and infrared scanning imagery. Impact problems related to highway location, dredge spoil placement, industrial and recreational development were considered in light of 'remote sensed' information acquired at various seasons. The effects of the seasonal aspects on acquisition cost, as well as the success of collecting comprehensive scientific information, were examined. Author

V1. Villemonte, J. R., et al. 1973. Remote Sensing in the Mixing Zone. In Remote Sensing and Water Resources Management; Proceedings of the Symposium, Burlington, Ontario, Canada, June 11-14, 1973, pp. 368-386. Urbana, Illinois: American Water Resources Association.

Studies of the dispersion and diffusion mechanisms by which pollutants are transported in natural river courses are related. The mixing zone at several industrial sites was studies by both ground and remote sensing methods. The advantage of coordination of these two methods is highlighted. The results can be used in the establishment of definite and rational water quality guidelines and in the development of a sampling and surveillance program by governmental and private agencies. IAA modified.

W1. Weist, W. M., Jr. and P. E. Greeson, eds. 1970. Hydrobiology, 'Bioresources of Shallow Water Environments': Proceedings of Symposium. 385 p. Urbana, Illinois: American Water Resources Association.

This volume contains 33 papers concerning the following topics: (1) Harvesting the Hydrosphere, (2) Conservation and Development of Bioresources, (3) Fresh-Water Bioresources, (4) Marine Bioresources, (5) Remote Sensing of Bioresources, and (6) New Methodology in Hydrobiological Studies. WRA

W2. Wezernak, C. T. and N. Roller. 1973. Monitoring Ocean Dumping with ERTS-1 data. In Symposium on Significant Results Obtained from the Earth Resources Technology Satellite-1: Vol. 1 - Technical Presentations, pp. 635-641. Houston: NASA.

Large volumes of municipal and industrial wastes are disposed of by means of dumping at sea. Disposal of wastes by barge dumping frequently produces surface films and waste fields whose fate and effects are not adequately defined. Frequently very large areas of the marine environment are affected. ERTS-1 data for the New York Bight were collected on August 16, 1972. Acid-iron wastes, sewage sludge, suspended solids, and major water mass boundary features could be seen in the study area. The surface movement of the wastes and the location of major water mass boundaries may be monitored. Synoptic coverage of the type available from satellite altitudes can be expected to contribute towards an understanding of surface circulation patterns in the area. WRA

W3. Wezernak, C. T. and F. C. Polcyn. 1970. Pollution Surveillance and Data Acquisition Using Multispectral Remote Sensing. Water Resources Bulletin 6:920-934.

Large scale water resources investigations and effective pollution surveillance programs require the development of additional instrumentation and techniques to supplement existing methods of data acquisition. As a result, interest is growing in the concept of remote sensing. A passive multichannel scanner system is capable of sensing reflected and emitted energy simultaneously in a number of narrow spectral intervals in the ultraviolet, visible and infrared region of the solar spectrum. The system basically consists of a spectrometer for dispersing the radiation spectrally and filtered detector arrays placed at the focal points of a double ended optical-mechanical scanner. In the field of water pollution control remote spectral measurements can be used to detect and identify effluent discharge. Temperature is closely related to water pollution. The ability to detect small temperature differences can be used to locate effluent outfalls including submerged outfalls. An important feature of the instrumental system used in this investigation is the ability to examine a scene in 17 bands distributed between 0.3 and 13.5 microns. This means that in addition to the detection capability referred to above, the system serves as a 17 channel spectrometer with electronic processing features. Each effluent is more clearly defined by examination at its optimum wavelength; and, hence, dispersion patterns of the effluent are best determined within a particular spectral band width. WRA

W4. Whipple, J. M. 1972. Aerial Surveillance of Water Quality in New York State. In Proceedings of the 38th Annual Meeting of American Society of Photogrammetry, pp. 199-211. Falls Church, Virginia: American Society of Photogrammetry.

Because thermal radiance can be used as a natural tracer of water circulation, it is useful in verifying the validity of point-sample locations and hydrodynamic models. Airborne equipment used by the U. S. Geological Survey in New York consists of a fixed-field radiometer, line-scanner with thermal references, a.c. and d.c. amplifiers, tape recorder, display screen, and film printer. Correlative information includes weather data and water-temperature records from the State automatic water-quality network and other sources. A centrally located aircraft permitted economy and good response to weather. Near Rochester on Lake Ontario the thermal radiances of the Genesee River, a cooling-water discharge, and the lake were measured. Other hydrologic features observed on imagery included spatial thermal pulsing of both artificial and natural discharges and a possible groundwater discharge into the lake. WRA

W5. Whipple, J. M. 1972. Remote Sensing of New York Lakes. In Geological Survey Research 1972, Chapter C. U. S. Geological Survey Professional Paper 800-C, pp. C243-C247.

Reverse flow through the outlet of Onondaga Lake and thermal activity associated with the spring mixing of Cayuga Lake were discerned on thermal-infrared imagery. Thermal radiances of natural and artificial discharges into Lake Ontario were measured, delineating the thermally pulsating nature of discharges into the open lake and thermal relationships between water masses. Quantitative imagery (radiometry) is useful in defining energy exchanges at the air-water interface. WRA

W6. White, R. G. 1971. Remote Sensing of Water Pollution. In Proceedings International Workshop on Earth Resources Survey Systems, pp. 303-321. Washington, D. C.: U. S. Government Printing Office.

Remote sensing, as a tool to aid in the control of water pollution, may prove to be exceptionally valuable in the next few years. It offers a means of making rapid, economical surveys of areas that are relatively inaccessible on the ground. At the same time, it offers the only practical means of mapping pollution patterns that cover large areas. New sensors and techniques, under development for the past several years, will obtain information about the nature and extent of pollution that previously could only be obtained by water sampling. WRA modified.

Y1. Yarger, H. L., et al. 1973. Water Turbidity Detection Using ERTS-1 Imagery. In Symposium on Significant Results Obtained from the Earth Resources Technology Satellite-1. Vol. 1, pp. 651-658.

ERTS-1 images of two federal reservoirs in Kansas exhibit good correlation with suspended load. The major reservoirs in Kansas, as well as in other Great Plains states, are playing increasingly important roles in flood control, recreation, agriculture, and urban water supply. Satellite imagery may prove useful for acquiring timely low cost water quality data required for optimum management of these freshwater resources. WRA

Y2. Yost, E. and S. Wenderoth. 1970. Remote Sensing of Coastal Environments Using Multispectral Photographic Techniques. In Hydrobiology, 'Bioresources of Shallow Water Environments', Proceedings of Symposium, pp. 274-302. Urbana, Illinois: American Water Resources Association.

The usefulness of multispectral color aerial photography for accurately and repeatably measuring basic environmental

parameters is demonstrated in a series of controlled experiments. The ability to establish image chromaticity differences for plants and trees under different solar illumination and atmospheric conditions is particularly significant. When coupled with spectroradiometric and biochemical analyses of coastal water masses, the ability of this technology to detect phytoplankton concentrations and sediments is promising. WRA

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